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INTRODUCTION

Although varying in detail according to the individual case the average child s electrocardiogram follows a simple pattern which may be recognized as that of a normal child rather through its lack of abnormal signs than by the presence of any definite form other than that by which it is characterized as belonging to the childhood group

In the following pages illustrative electrocardiograms of average children are shown together with tracings frequently found in cer tain abnormal conditions It must be mentioned in this connection that the electrocardiogram may be of average form even in a badly damaged heart and it is to be remembered that the electrocardiogram is only an adjunct to a clinical examination

The findings in this book are based on the study of electrocardiograms * taken on 500 children from the wards and clinics of St Luke s Hospital New York City, and from private practice For the sake of uniformity the tracings have been taken with the child in a sitting or propped up position We have found that children do not fear the examination while in a sitting position as they often do when supine and again cardiacs in failure cannot lie flat during the test Infant and child sized electrodes were used for smaller children

The tracings of 350 physically normal fourth year students † be tween the ages of 22 and 26 years have been used as young adult tracings for comparison with this group

The deflections and intervals present in a normal cardiac cycle are considered individually and as a whole Normal variations are noted and abnormal tracings are described Characteristics found in each

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0 078 second and the average rate is 112 and from 6 to 13 years the time consumed is 0 08 second while the average rate is 94 (Tables 1 and 7) In the young adult the average P width is 0 10 to 0 11 second

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The atrial T wave or wave of atrial repolarization may be recog nized as a depression in the P R segment or it may fall after the QRS complex. The Ta wave is best seen in a v block of high de gree and is apt to be more notice able when P is high (Fig 56C i and ii)

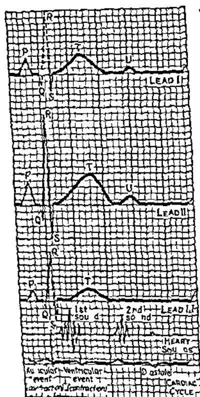


Fig. 1 Diagram showing events of the cardiac cycle by standard limb lead and sound wave cardiograms Vertical squares = 1 mv Horizontal squares = 0 04 second

The P R interval is the time taken for the impulse to pass from the s a node to the ventricular muscle The interval starts at the beginning of P and ends at the start of the R or of the Q wave if present It includes the time taken to depolarize the atrial muscle (P wave) plus the time in which the impulse is delayed at the a v node and the main bundle of His until the onset of ventricular de polarization (P R segment) The interval varies with heart rate and body size being shorter in more rapid and small hearts As would be expected the interval is shorter in the infant than in the young child and in the child than in the young adult The average time of the P R interval in the 1 to 8 week-old infant is 0 107 second with an average rate of 164 per minute in the 2 to 12 month-old baby 0 116 second with a rate of 143 and in the 1 to 6-year-old child it is 0 130 second with an average rate of 110 5 In the older youngster of 6 to 13 years 0 152

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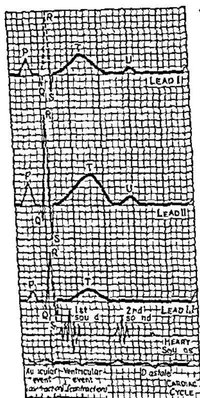


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during held inspiration there is an increase in the size of the R deflection in these leads (Patient referred by Dr *Ruth Cudmore*)

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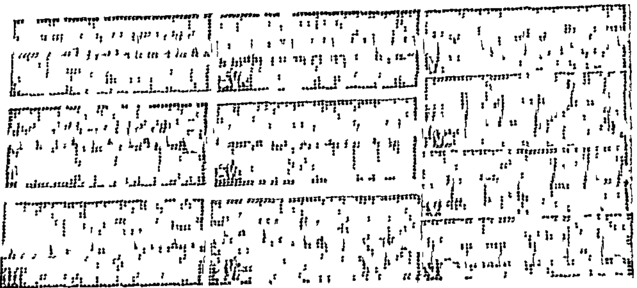


Fig 4 Electrocardiogram taken on 3 week old premature boy The voltage is low The heart rate is 160 *There is slight elevation of the R T segment in lead 2*

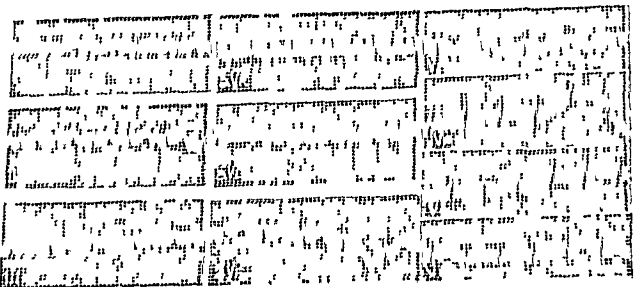


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Q or R to its end R or S The average of 0 065 in the child is shorter than that in the young adult in whom the upper limit is 0 10 and occasionally 0 11 second The QRS interval is usually shortest over V_2 where the electrode is nearest the heart The time varies with age body size and build and heart rate being

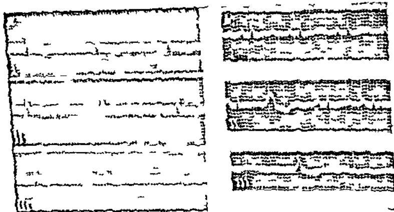


Fig 5 a Marked low voltage in 17 year-old girl with untreated hypothyroidism Note inversion of *T waves in leads 1* and 2 slow heart rate and sluggish a v conduction

b For comparison similar low voltage present in a 12 year-old girl with constrictive pericarditis *The rapid rate* is the distinguishing feature Ventricular premature contractions present in leads 2 and 3 are coincidental

greater in heavier hearts and *shorter in infancy* in small hearts and in those with rapid rates

The interval is commonly increased where there is a fibrosis of heart muscle in cases where a bundle *branch* is blocked and in right and left ventricular hypertrophy *It may* be transiently prolonged *in* acute infections as *in acute rheumatic* fever and during certain therapeutic procedures as under quinidinization *In the* Wolff Parkinson White syndrome the interval *is lengthened*

The Q wave is the term given to the initial downward or negative deflection of the depolarization *complex* of ventricular musculature and is due to an initial potential difference directed away *from the* electrode

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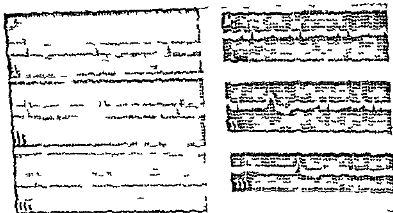


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muscle last to be activated such as the lateral and posterior basal wall of the left ventricle and are absent in tracings taken over muscle initially invaded or first to be activated as found over the right precordium The child s Q wave is usually absent over V_1 and V and is deepest in leads 3 and V_6 It is normally narrow with an average width of 0 0175 second and depth of 0 036 mm with a maximum of 7 5 mm

Q waves are frequently seen in lead 1 and in precordial leads facing the left ventricle in left ventricular hypertrophy They are common in lead 3 and precordial leads over the right ventricle in right ventricular hypertrophy

In left bundle branch block Q waves are absent in tracings with the electrode facing the left precordium a distinguishing point from those of left ventricular hypertrophy

Abnormal Q deflections are usually wide and greater than 25 per cent of the highest R deflection in the l ad

The Q T interval starts at the beginning of Q and terminates at the end of T It includes the time taken by the impulse to invade the ventricular muscle and the time for the complete return of the muscle to its resting or polarized state

The interval varies with heart rate sex and age It varies also with the electrolyte and water balance of the blood as with potassium loss and sodium retention with calcium and phosphorus changes or disturbances of carbohydrate metabolism androgenic and other factors The interval is increased in heart failure in myocarditis and in ventricular hypertrophy during toxic states in quinidine intoxication and in avitaminosis as well as in hypopotassemia and hypocalcemia It is shortened in hypercalcemia and with digitalis effect and occasionally in acute pericarditis The lability of the interval owing to its response to such external factors makes it unreliable as a constant measure of precision However although it is prolonged in most infectious diseases including rheumatic fever it is useful in determining the presence of activity in questionable rheumatic infection when serial tracings are made (Figs 17A B, and C)

The average measured Q T interval together with its related average R R cycle may be converted to a uniform standard through

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to its peak is shorter in leads from the right precordium than in those taken over the left precordium of the normal child There is a slight increase in this time interval or delay in the intrinsicoid deflections as the child grows older but the relative ratio of right to left continues (Table 4) The peak of R divides the QRS deflections due to muscle activated before from that depolarized after the *impulse* reaches the muscle under the exploring electrode There may be two upward waves in the QRS complex separated by a downward deflection The second wave R^1, is often seen when the electrode is over the base of the heart from late activation of the conus If slurring is present in the highest R near its apex abnormal conduction is probable The wave is commonly extremely high in congenital heart disease (Fig 13a) A late R peak in V_1 with early intrinsicoid deflection in V_6 is seen in right ventricular hypertrophy and right bundle branch block (Figs 13a and 46)

S wave is the designation of the final downward wave of the depolarization complex of ventricular muscle owing to negative cavity potentials being transmitted through a completely depolarized wall to the electrode over its epicardial surface

The average depth of the S deflection in the standard limb leads of childhood is 1 61 mm and over precordial leads 6 66 mm It is deepest in leads 2 and V and in the younger age group It is often absent in the child and may vary in depth in I 3 during respiration (Figs 2 and 3)

S waves are deepest in tracings from that portion of the wall where activation is completed first as is usual in unipolar leads taken with the terminal over the right ventricle and absent where it is completed last as over the left ventricle

The junction or J ' is the term used for the meeting point of the QRS complex with the S-T segment

The S T segment is represented by the duration of time between the end of the S wave and the start of the T deflection It is the interval of time between the completion of depolarization and beginning of repolarization of ventricular musculature This segment varies according to the heart rate being longer in slow rates and shorter when the rate is rapid. The average duration of the S-T

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is also opposite to that of the T deflection T wave changes from involvement of epicardial and endocardial ventricular surfaces may best be seen in unipolar limb leads

U wave is the term given to the positive after potential of muscle contraction It starts at the end of the T wave and is usually not visible in the child s tracing However in slow rhythms and in the presence of hypopotassemia it may occasionally be fairly prominent (Figs 53c and 55C)

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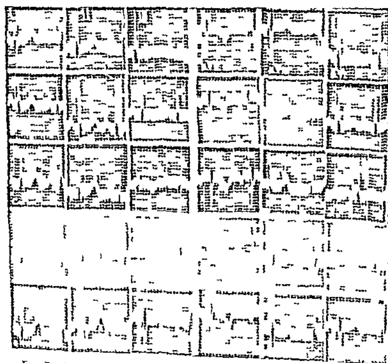


Fig 7 Standard and unipolar limb leads of children with average precordial leads showing
a [illegible]
b [illegible] in 11 year-old girl
c
d
e

Change in heart position with attendant variations in the relative relationship between the right and left ventricles may be found in the same child During deep held inspiration for example the diaphragm descends and the heart being relatively fixed at its base will in following rotate on its longitudinal axis in a clockwise direction so that the left ventricle lies below the right ventricle

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deviation may depend on a mechanical shift in the relationship of the two ventricles to the chest or it may be due to disease or mal formation in which hypertrophy of either ventricle is commonly present

The electrocardiogram of the normal child is peculiar to that child Apart from the changes consistent with growth and from those varia tions seen in the axis deviation of the ventricular curves on rotation of the heart around its longitudinal axis the general characteristics present in a normal child s electrocardiogram are retained throughout childhood years with remarkable constancy

Such differentiating points appearing to be inherent qualities of the individual s cardiac activity are inverted or diphasic P waves in leads 2 or 3 the presence of U waves the slurring or splitting of QRS compl xes the origin of the S-T segments and the ratio of the voltage of L1 to L3

Many of these signs are due to the constitutional type of the in dividual child, and they may be found in several members of one family Similarities in the tracings of siblings are often so striking that differentiation of the electrocardiograms is rendered difficult as in the records of the siblings illustrated (Figs 8 and 10) In Fig 9 the tracings of two children a brother and sister are compared A resemblance is again present and shows low voltage of lead 1 in both and a diphasic T3 in one and inverted T3 in the other Higher P wave amplitude is present in the girl and greater T wave voltage in the boy as is usually seen in comparison between the sexes

The P wave of atrial activity is gr ater in height in the standard limb leads of girls between the ages of 6 and 12 years than it is in boys of that age group The components of the QRST group of the standard limb leads are of greater amplitude in boys than in girls in the 6-to-12 age group (Fig 9) In this connection it is of interest to note that Beneke in 1910 observed in his studies on the anatomy of the heart that the relative volume of the atria to the ventricles was greater in the female than in the male

At 12 years of age all standard limb lead deflections are on the average greater in amplitude in boys than in girls The average heart rate in girls of 6 years and under and of 12 years and over

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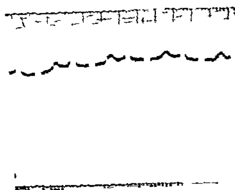


Fig 10 Tracing showing leads 2 from two brothers (A and B) 5 and 7 years old who had congenital heart lesions. Incomplete a v block is present in both boys

standard lead electrocardiogram and the changing electrical field of the heart

For this study a record is made in the form of a loop by the junction of the apices of several instantaneous axes which are determined from the tracings of two or three simultaneous standard leads and noted at consecutive periods Although time-consuming with present methods the vectorcardiogram promises to be a valuable asset especially in the study of congenital heart lesions

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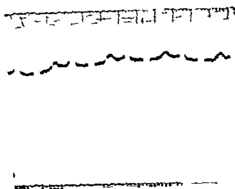


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Standard lead 2 Electrodes are placed on the right arm and left leg so that potential variations from the right arm and left leg roots are noted in the tracing (When considering simultaneous points of the curves in different leads lead 2 equals the sum of leads 1 and 3 for all practical purposes) P waves are usually upright and greatest in this lead They may show a slurring on the upstroke and rarely they may be inverted as a positional effect Q waves are often absent but they may be deep R waves are usually tall When present S deflections are often deepest in lead 2 T waves also reach their greatest standard lead height in this lead very rarely they may be inverted because of heart position

Standard lead 3 With electrodes placed on the left arm and left leg potential variations from the left arm and left leg roots are registered in the tracing P waves are inverted in lead 3 in about 10 per cent of *normal children* Upright R waves usually dominate the QRS complex in the normal child in this lead however in a horizontal electrocardiographic position left axis deviation with deep S or QS waves may be seen Q and S waves are often deep and may disappear or vary with position T waves are inverted in lead 3 in about 35 per cent of normal children

In contrast to these bipolar leads *unipolar* leads record potentials from one extremity only the exploring electrode the other the indifferent electrode being at the so-called zero potential As the deflections in *unipolar limb leads* are small augmented unipolar limb leads as introduced by Goldberger are almost universally used These are designated as aV_R aV_L and aV_F leads Unipolar leads are valuable as a means of comparison between the right and left ventricles The electrocardiographic curve varies according to the portion of the heart that faces the limb root on which the electrode is placed This may be roughly either the great orifices of the heart or the right or left ventricle In the normal heart a relationship exists between standard and unipolar limb leads so that if L1 resembles L2 VR is similar but inverted and if L3 is the inverse of L1 VL resembles L1 also if L2 and L3 are similar VF is also similar Again VL − VR = L1 VF − VR = L2 VF − VL = L3 (Fig 7)

VR the unipolar right arm lead or as is more commonly used

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but may be diphasic or rarely inverted The usual QRS complex in the VL lead of a child consists of an RS curve often of low voltage However the form depends on the electrical position of the heart and it is occasionally difficult to determine whether the base of the heart or the epicardial surface contributes more to the form of the QRS complex in this lead If the electrocardiographic position is vertical the left arm root will face the clockwise rotated right ventricle and the tracing will show an rS complex and inverted T wave If in a horizontal electrocardiographic position the left shoulder will face the counterclockwise rotated left ventricle and a qR will be inscribed and the P and T waves may be inverted when they will also be so in VR leads The semivertical electrocardiographic position shows low voltage of QRS in VL and the semihorizontal electrocardiographic position gives low voltage in VF The S-T segment, which is usually isoelectric is occasionally elevated or depressed (Fig 7)

V F, the unipolar left leg lead or aV_F the augmented unipolar left leg lead shows the potential variations of the left leg or left hip joint similar to those of the surface of the diaphragm facing the heart P waves are usually upright in VF leads The form of QRS in the child s VF lead depends upon the electrical position and rotation of the heart In the vertical electrocardiographic position VF is similar to leads over the left ventricle and will show Rs or qRs ventricular compl xes with high R waves In the horizontal electrocardiographic position the QRS form in VF resembles those over the right ventricle showing deep S waves which may disappear on deep inspiration (Fig 2) When the heart is in the semihorizontal position the QRS complexes in VF are small When there is forward rotation of the apex the left leg lead will face the epicardial surface of the left ventricle and a qR will be seen in VF and when there is backward rotation an rS or Rs will be present reflecting potentials from the right ventricle

Q waves in VF may be seen in normal tracings They are usually followed by tall R waves with a late peak A broad Q with small narrow R is abnormal as is true also when it is not accompanied by a QR in VR Rarely T waves may be inverted normally in VF but they are usually positive in this lead

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CHAPTER IV

Unipolar Precordial Leads

Precordial Unipolar Leads According to the criteria of the New York Heart Association precordial leads are taken on the chest at desired points over a line extending from the right sternal margin at the level of the fourth intercostal space to the junction of the left midclavicular line with the fifth intercostal space continuing at this level around the left chest Right-chest leads are taken over the right chest in a similar manner (Fig 11A and B)

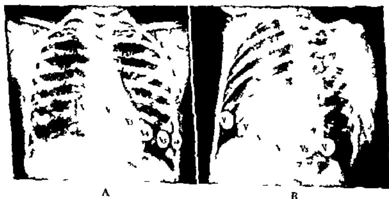


Fig 11 Positions of unipolar precordial leads shown by pennies on chest of 6 year-old asthmatic girl A. Posterior anterior view B Left anterior oblique view (After Hecht)

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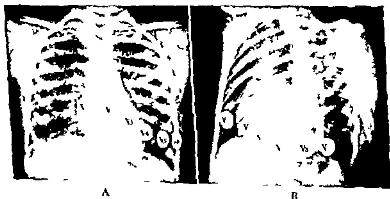


Fig. 11. *Positions of unipolar precordial leads shown by pennies on chest of 6 year-old asthmatic girl.* A. Posterior anterior view. B. Left anterior oblique view. (After Hecht.)

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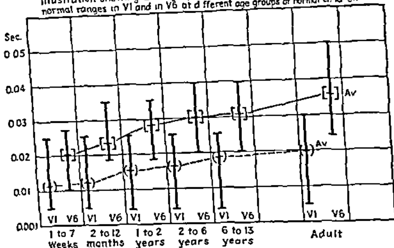


Table 4

diphasic in the infant becoming less commonly so in the older child where they are usually clearly visible and with greater amplitude than V in other chest leads In the newborn and the infant under 8 weeks an isolated R wave or Rs curve followed by an inverted T wave is the rule for the QRS form in V_1 The amplitude of the R deflection in V_1 gradually decreases with the age of the child so that in the 6- to 13 year old age group an rS is the usual form although the T waves continue to be inverted Very rarely the R waves are absent and a deep QS is present The intrinsicoid deflection occurs early in the course of the QRS group (Table 4) In the normal child T in V_1 is rarely upright and the ST junction is frequently elevated

The various form of the QRS complex found in V_1 are attributable in most part to the different positions in which the heart may be found If the electrode should lie over the right ventricle the initial deflection will be an R wave If it lies over the right atrium and faces the great orifices of the heart as it does when the heart is displaced backward and to the left, a QS or rS will be present In this case R is prominent in aV_R also and the transition zone will be shifted to the left.

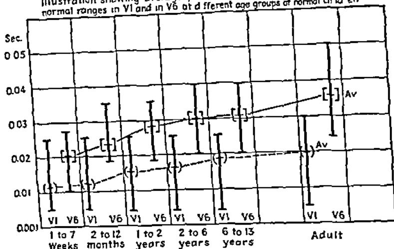


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V_2 (The tracing is taken with the exploring electrode placed at the left costosternal margin at the level of the fourth intercostal space) P waves are occasionally inverted or diphasic in this lead in the child The usual QRS form is an RS curve Rarely a small q wave is seen in infants under 1 year of age

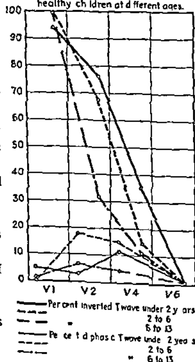


Table 5

S waves are usually deepest in this lead although in the younger age groups especially S may be deeper in leads V_3 and V_4 than in V T waves are commonly inverted in V in the younger child They are inverted in 64 3 per cent of normal children under 6 years and 27 2 per cent in those of 6 to 13 years (Table 4) The S-T junction is usually isoelectric although it may be highly elevated or depressed in this lead (Fig 12)

V_3 (The exploring electrode is placed midway between the positions for V and V_4) Because of the small size of the child s chest this lead and that of V are frequently omitted from the child s electrocardiogram except in special instances The initial deflection in V_3 is usually an R wave and T waves are usually inverted in children under 6 years of age

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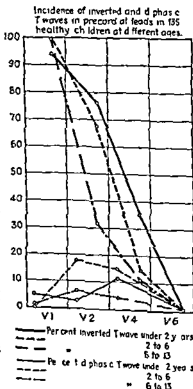


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CHAPTER V

The Child s Electrocardiogram in Disease

Bundle Branch Block

Bundle branch block is due to an obstructing defect or anomaly in the conduction pathway of one or the other of the branches of the bundle of His resulting in delay in activation of the affected ventricle Absent Q waves and broad notched or bifid R waves with delayed intrinsicoid deflections and widened QRS complexes of 0 10 second or more characterize the tracings over the epicardial surface of the blocked ventricle of the child Narrow R deflections and broad S waves with widened QRS intervals are present over the opposite ventricle (Table 6 and Figs 13a and b 30 35 and 41A)

Bundle branch block is not rare in congenital heart disease especially in lesions of the atrial septum and less commonly of the ventricular septum It may be found in long standing cases of aortic regurgitation and mitral stenosis

As a transitory finding bundle branch block may be seen in patients with acute infections such as diphtheritic myocarditis and acute rheumatic carditis In the early stages of the chronic form transient bundle branch block may be noted It may be seen as a manifestation of toxicity during drug therapy such as with quinidinization

Arborization block is the term occasionally used in describing bundle branch block which shows low voltage in the standard limb leads (Fig 14)

(Text continued on p 36)

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Fig 14 Arborization block (bundle branch block with low voltage) shown in standard limb leads of 10-year-old girl with clinical signs of ventricular septal defect

Right BBB	*Left BBB*
NOTCHING OF QRS COMPLEXES WITH QRS INTERVAL 0 10 SECOND OR MORE	NOTCHING OF QRS COMPLEXES WITH QRS INTERVAL 0 10 SECOND OR MORE
Form of QRS curve in limb leads depends on heart position It is usual to see late wide S in leads 1 and VL, late notched R in VR with R in leads 3 and VF	The QRS outline in limb leads *depends* on the heart position but usually shows high R waves in leads 1 and VL with deep S or QS in leads 3 VF and VR
QRS complexes in V and V usually show rsR curves with wide and tall R and inverted T waves	QRS in V and V usually shows QS or rS with elevated R T segment and upright T
QRS in V V and V usually shows qRS with prominent S and upright T	QRS in V and V usually shows absent Q waves notched R waves with depressed R T segment and inverted T
The intrinsicoid deflection is delayed over the right precordium starting 0 02 second or more after the onset of the QR curve and is normal over the left ventricle	The intrinsicoid deflection is late over *the left* precordium starting 0 04 second or more after the QRS onset and is normal over the right ventricle

Table 6 Differentiation between right and left bundle branch block in the child

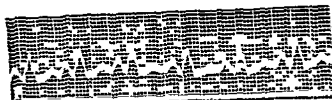


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sinus or vagal stimulation The P J segment will then be seen to be equal to the P J segment found during a cycle of ectopic rhythm This is not the case in true bundle branch block, where the blocked P J segment is increased in duration

Cardiac Hypertrophy

Cardiac hypertrophy is usually first localized to a single heart chamber There is an increase in the size and weight of each muscle fiber in the muscle mass affected Other chambers *may* or *may not* be involved later in the course of the disease

Atrial hypertrophy may be found in patients in whom an increased load is present in the atria of the heart as in those with pulmonic tricuspid or mitral stenosis atrial septal defects pulmonary disease and certain types of myocardial infarction

In such cases where there is marked atrial activity the P waves may be wider than 0 11 second and as high as 2 5 mm They may be peaked tall broad notched or slurred and are best seen in V_1 V VR and VL leads (Fig 56A and C)

Hypertrophy of either ventricle commonly shows a delay in the duration of the intrinsicoid deflect on in the tracing taken over the hypertrophied ventricle in comparison with that taken over the normal ventricle The R waves are usually markedly increased in voltage and small S deflections with depressed S T segments may be seen in leads facing the hypertrophied ventricle while the inverse is found over the normal ventricle The QRS interval is moderately increased to 0 1 or 0 11 second over an hypertrophied left ventricle and the transitional zone will be noted to be nearer the affected ventricle than normal

Left ventricular hypertrophy, as may commonly be found in such conditions as tricuspid atresia and aortic stenoses marked coarctation of the aorta and long standing severe patency of the ductus arteriosus may show the following changes

V_1 and leads facing the right ventricle show rS or QS waves with no delay in the intrinsicoid deflection The S-T segment is elevated in these tracings and T is upright

V_6 and leads facing the hypertrophied left ventricle commonly

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Differentiation of right ventricular hypertrophy from right bundle branch block is difficult at times The shorter QRS interval and absence of notching of the R waves over the hypertrophied ventricle together with the presence of small R waves over the left pre cordium suggest hypertrophy rather than right bundle branch block (Figs 13a 36A and 46)

Ventricular Strain

Ventricular strain* has been described as a functional disturbance of heart muscle which is usually reversible and whose electrocardiographic signs are similar to those of muscle injury which affects the repolarization process only S-T segments become depressed and T waves inverted while the QRS curves remain unchanged It has been suggested that when the S T T changes as noted above are found without increase in amplitude of R and S waves ventricular strain without hypertrophy may be presupposed and that when the S-T T changes described above are not found in the presence of increased amplitude of R and S deflections hypertrophy without ventricular strain is present also that combined QRS S-T and T changes suggest the presence of hypertrophy with strain

Ventricular Myocardial Infarction

Ventricular myocardial infarction follows an acute ischemia of a part of ventricular muscle whose blood oxygen supply is either sud denly cut off or becomes inadequate for its nutritional demands The affected muscle becomes necrotic and is replaced by fibrous tissue The lesion is rare in the child and the diagnosis may be easily missed

Coronary circulation in the child differs from that of the adult. In the

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* There has been criticism of the use of the term "ventricular strain" in electrocardiographic interpretation.

The lesion is transmural and is most frequently found in the anterior and apical portions of the left ventricle which is the area supplied by the anterior descending branch of the left coronary artery the vessel most usually affected

Occlusion of the right coronary artery will cause infarction of the posterior wall of the left ventricle and often includes the posterior portion of the septum in the affected area

The electrocardiographic diagnosis is made only on characteristic changes in the QRS complexes with S T displacements and, or typical T wave changes

The first electrocardiographic sign of myocardial infarction which may be found is typical of muscle injury and is represented by an upward displacement of the RS T segment over the affected area The elevation is usually transitory and of short duration and it dis appears when the affected *muscle dies or recovers*

The volta e of the positive intrinsic deflection decreases and may disappear while a deep ne ative or Q wave appears over the necrosed area this being incapable of impulse response allows the potential variations of the adjacent ventricular cavity to be transmitted through the infarction to the overlying electrode If portions of living muscle are present in the lesion small R waves or notching of the Q waves will be seen These signs may be transient or permanent

T waves registered from marginal epicardial portions of the necrosed area may become deeply inverted in their terminal portions and may remain so indefinitely

When electrocardiographic signs of myocardial infarction are present progressive changes are early and rapid in serial tracings

An anteroseptal wall infarction of the left ventricle may show typical changes in L1 VL V_1 V V_3 and V_4 In anterolateral wall infarction disturbances may be seen as well in leads V and V_6

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... complex is present in ... and depressed and inverted T waves The S-T segment is depressed in V and elevated in V_4. Interpolated and ectopic auricular beats re present in leads I and in aV

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Rheumatic Fever

Transitory electrocardiographic changes are usually present * some degree in acute rheumatic carditis

During my interneship and later while attending on the Childre Service at Bellevue Hospital in the 1920 s I studied a group of 1 children of 13 years and under who had active rheumatic card and to whom digitalis was given only rarely and sparingly at t time *Electrocardiograms* were also then repeated only occasiona but each child in the group had at least one tracing *taken Of th* 61 showed first-degree a v block 11 second-degree block whil *4 children* complete a v dissociation was present Atrial fibrilla *occurred* in 9 cases of whom the youngest was 9 years *old (7 of tl children* died within a few month after the onset of fibrillati 1 child showing atrial fibrillation combined with complete a v bl and 1 ventricular fibrillation as a *terminal* event

The findings depend upon the severity and location of the le: If these *are diffuse* abnormalities may be found in all parts of cardiac cycle with P wave *and QRS* curve widening and notcl S-T displacements and T wave changes Disturbances of im conduction in the uncharted *pathways of* the atria or in the bu of His and its branches are recognized by a widening of the P when the lesion is in the atria or by a prolongation of the P R QRS intervals when in the *a v node* the bundle or its bran When there is delay in the invasion and retreat of the im through inflammatory reaction of the ventricular mu cle the segment shows an increase in time *duration* If the epicardial su of th heart is affected as in acute pericarditis S-T displacement

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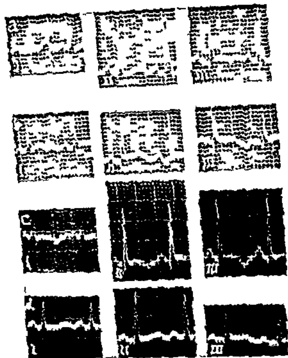


Fig 17A Standard limb leads taken over consecutive weeks on a 12 year

c The T deflections have become deeply inverted in all leads and the S T segments are isoelectric but co.. tinue to show upward convexity and the QT of 0 407 second is again above normal

d The tracing returns to original form. The QT continues to be prolonged at 0 403 second

Acute Rheumatic Pericarditis

Acute pericarditis frequently shows a typical electrocardiogram in the early stages of the acute p oc ss The changes are usually rapid and transitory depending however on the nature of the infection They are characteristic of epicardial injury and affect first the deviation of the S T segment and later the T deflection The first sign is a notice able elevation of the S-T segmen in the three standard limb leads

(Text continued on p 48)

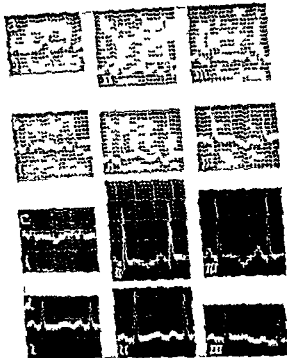


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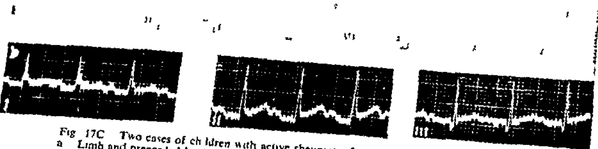


Fig 17C Two cases of children with active rheumatic fever in early stage

a Limb and precordial leads of an 8 year-old boy showing rapid sinus rhythm and sluggish a v conduction The P R interval is 0 20 second

b Standard limb leads of an acutely ill boy of 13 years with inflamed and tender joints The P R interval is 0 21 second and the R T segments in leads 2 and 3 are elevated The P waves are wide and the P R segment is depressed in leads 1 and 2

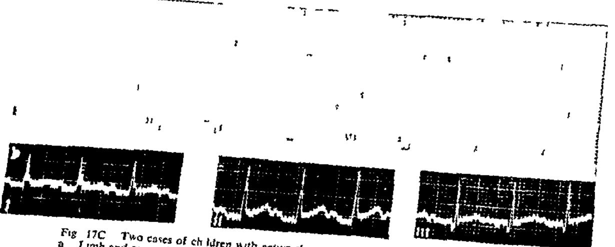


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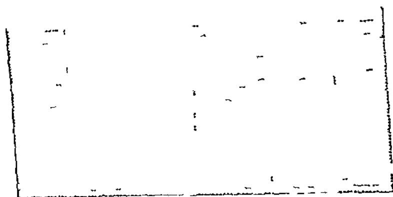


Fig 19 Standard and unipolar limb leads and unipolar precordial leads from a 16 year-old boy with *inactive* rheumatic aortic disease and hypertension The tracing shows sinus rhythm with marked left axis deviation and early left ventricular hypertrophy *The deep S present in lead 3 does not change on* deep inspiration in cases of left ventricular hypertrophy

hydrostatic pressure in the pericardial sac The Q T interval is usually normal

Constrictive pericarditis may be recognized in the electrocardiogram by the finding in serial tracings of a rapid and steady decrease of wave amplitude in all leads together with an increase in the heart rate T waves are frequently inverted In the late stages of constrictive pericarditis the voltage is extremely low Similar low voltage is seen in advanced untreated hypothyroidism where the heart rate is however very slow in contrast to that of constrictive pericarditis (Figs 5b and 23)

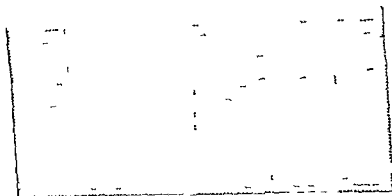


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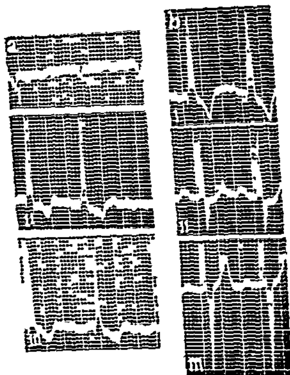


Fig 21 a Atrial fibrillation in case of 10-year-old boy with rheumatic carditis and mitral stenosis. Coarse "f" waves of fibrillation and right axis deviation are present. Digitalis effect noted by depressed and inverted T waves in leads 2 and 3.

b Standard limb leads taken from 14-year-old boy with aortic insufficiency of rheumatic origin. Conduction is delayed in the entire pathway, the P-R interval being 0.24 second and the QRS 0.11 second. Marked left axis deviation is present.

effect may result from an abrupt reversal of shunt in a wide septal defect. The electrocardiogram often shows characteristic signs of right ventricular strain and hypertrophy of sudden appearance and if the patient should survive as sudden disappearance. There are deep S waves and depressed S-T segments in lead 1 with deep Q and elevated S-T segments in lead 3. T waves are inverted in lead 3 and over the right precordium where also R waves are often noted. The condition is most rare in a child.

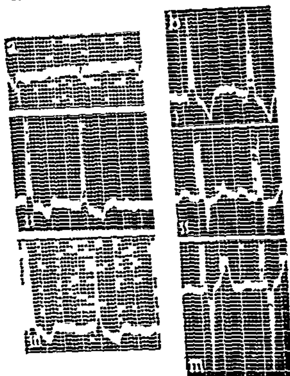


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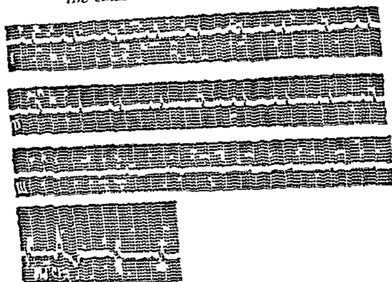


Fig 73 Standard limb lead tracing with reversed type lead CF4—seen occasionally in old editions of books on electrocardiography—from 12 year-old girl with constrictive *pericarditis* There is marked low voltage The heart rate is rapid (113 per minute) The P R interval is 0 16 second The Q T interval of 0 403 second is prolonged T waves are inverted in lead 3 and slightly diphasic in leads 1 and 2 An occasional ventricular premature contraction is present

Digitalis and the Electrocardiogram

The desired and usual therapeutic effect of digitalis is in slowing the heartbeat Besides acting directly on heart muscle digitalis acts on the cardioinhibitory center and through vagal stimulation depresses the conduction of impulses between the atria and ventricles The heart rate is lowered the P R interval is lengthened and the Q T interval is shortened as the lowered level of sensitivity to calcium present in the heart in failure again becomes normal The normal upward concavity of the S-T segment is deepened and the segment becomes depressed except occasionally in the VR lead where it may be elevated These effects may be seen in precordial as well as in standard limb leads Maintained digitalis effect is followed by a lowering of T wave amplitude and final inversion of the T deflection (Figs 21a 25 and 36B)

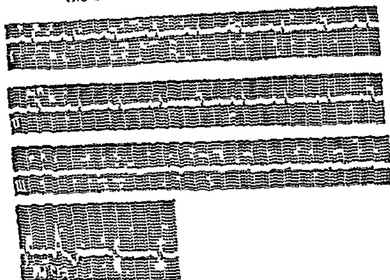


Fig 23 Standard limb lead tracing with reversed type lead CF4—seen occasionally in old editions of books on electrocardiography—from 12 year-old girl with constrictive *pericarditis* *There is* marked low voltage The heart rate is rapid (113 per minute) *The P R interval is 0 16* second The Q T interval of 0 40? second is prolonged T waves are inverted in lead 3 and slightly diphasic in leads 1 *and 2 An occasional* ventricular premature contraction is present

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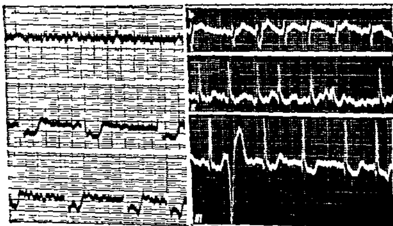


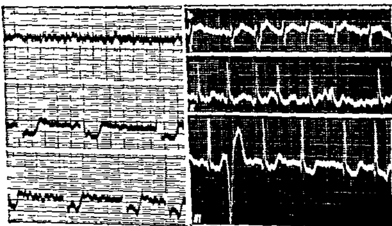
Fig 25 a b Digitalis effect seen in standard limb leads of two children receiving digitalis for heart failure

a Tracing shows slow atrial fibrillation with slight right axis deviation and coarse atrial oscillations S-T segments are deeply depressed in leads 2 and 3 From a 10-year-old boy with mitral lesions and failure

b Rapid atrial fibrillation with right axis deviation coarse atrial oscillations and frequent ventricular premature contractions The S T segments in leads 2 and 3 are depressed and concave downward Tracing of a 9 year-old boy with mitral disease

c Tracing showing digitalis effect in an adolescent boy (A F) with diagnosis of rheumatic aortic insufficiency

Sinus rhythm is present with frequent interruption by ventricular premature contractions There is left axis deviation with semihorizontal electrocardiographic position of the heart The S T segments in leads 1 2, aV_L, aV V V and V are depressed and concave upward



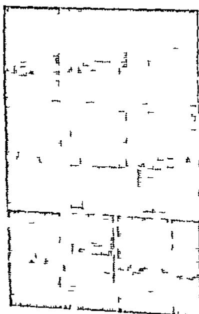


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CHAPTER VI

The Electrocardiogram in Congenital Heart Lesions

Congenital Heart Disease and the Electrocardiogram

The electrocardiograms of many children with congenital heart lesions show no differentiating signs from those of the normal child's tracing Similar negative findings may be seen in the electrocardiogram of the newborn infant with congenital heart disease in whom characteristic changes may appear as soon as the effect of mechanical strain becomes evident on ventricular muscle and anatomic position

Other tracings of children with congenital heart lesions however fall under specific types which may aid in the diagnosis of the lesion or lesions present Some give electrocardiographic evidence of marked positional changes owing to abnormal rotations of the heart caused by the cardiodynamics of the lesions present Some tracings again may be typical of right or left ventricular "strain or hyper trophy It should be noted in this connection that ventricular hyper trophy is recognized best in the unipolar precordial leads and that deviation of the electrical axis to the right or left in the standard limb leads is frequently due to rotation of the heart and reliance on this sign as an indication of hypertrophy is often misleading. Marked right or left axis deviation is however usual evidence of hypertrophy of the respective ventricle Other tracings may show diphasic QRS complexes in two or more of the standard limb leads in which the

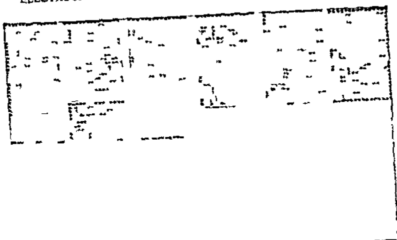
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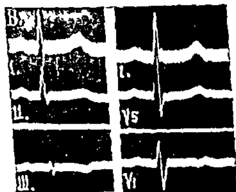


Fig 29 A Electrocardiogram of 2 year-old girl (L de R) with coarctation of the aorta (Acknowledgment to Dr Edward Hardy) The tracing shows sinus rhythm with no deviation of the electrical axis and indeterminate electrocardiograph position

B Electrocardiogram taken in E M a 14 year old girl with coarctation of the aorta and arrested subbacterial endarteritis and calcified mycotic aneurysm below the site of coarctation The findings were corroborated by autopsy The electrocardiogram shows sinus rhythm with low voltage in lead 3 (The clinical findings in this case were described in *Am Heart J* 20 3 7 1940)

Subaortic stenosis Owing to a developmental arrest in the involution of the bulbus cordis a shelflike band of tissue persists below the aortic valves Electrocardiographic findings are similar to those noted above (Fig 30)

Bicuspid aortic valve No characteristic electrocardiographic signs are found in this lesion (Fig 31)



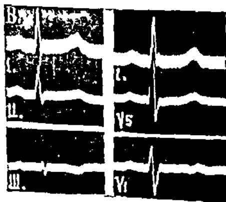


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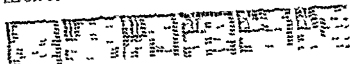


Fig 33 Tracing showing sinus rhythm with right axis deviation and heart in the vertical electrocar[illegible]
The
arter
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The electrocardiogram in anomalies of the coronary arteries Coronary arteries may vary in size in number in distribution and in origin The most important clinical anomaly of the coronary system i found in those cases where the coronary artery arises from the pulmonary artery Here signs of coronary insufficiency and myocardial ischemia appear Patches of wedge shaped degeneration

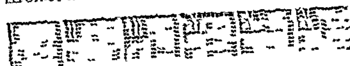


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Fig 35 Right bundle branch block is seen in this case (A F) of at al [illegible]

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partial situs inversus the chambers of the heart are reversed A mirror image of lead 1* is present in the electrocardiogram and leads 2 and 3 are interchanged Two of the unipolar limb leads are also interchanged VR taking the character of the normal VL lead and VL resembling a usual VR lead Precordial leads are similar to those over the right chest in the normally placed heart (*Figs* 38 *and* 39)

Less commonly an *isolated dextrocardia with reversal of heart chambers* is seen Differentiation from the above form is made by physical and fluoroscopic examination as electrocardiographic changes described above are also present in this condition (Fig 40)

Isolated dextrocardia without reversal of heart chambers may be congenital but is commonly associated with external factors which cause a marked counterclockwise rotation of the heart on its long axis The right ventricle will then be shifted to the right and dorsad

* Looking into a mirror held on a slant in front of the tracing before the observer lead I will appear upright Also if the right and left arm electrodes are reversed the outline will be upright

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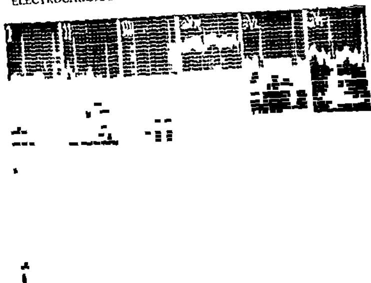


Fig 37 Trac... with severe "colic... nosis and d ed sh... murmurs were at... in this type of ca... They are...

...ually out was *prominent* and tortuous The *left* atrium and ventricle were hypertrophied and dilated and showed extensive fibrosis Microscopically *endocardial* fibrosis was marked Subendocardial necrosis and myocardial degeneration and fibrosis were present.

of Group 3 The positional changes present however disappear on removal of the offending agent (Fig 41A and B)

Dextrocardia combined with *pulmonic stenosis* shows a mirror picture of lead 1 in which a large R deflection is present R is also prominent (Fig 42)

The electrocardiogram in uncomplicated Eisenmenger's complex In this not uncommon congenital heart lesion a dextroposition of the aorta with a high interventricular septal defect and dilated or

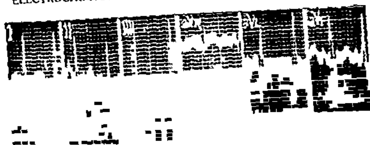


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of Group 3 The positional changes present however disappear on removal of the offending agent (Fig 41A and B)

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The electrocardiogram in uncomplicated Eisenmenger's complex In this not uncommon congenital heart lesion a dextroposition of the aorta with a high interventricular septal defect and dilated or

gram may show inverted T waves in two or more standard limb leads Right axis deviation has not been observed Depression of the S-T segments may be marked (Fig 44)

The electrocardiogram in pure pulmonic stenosis Pulmonic stenosis may be of valvular type in which the three semilunar cusps are fused or it may be infundibular in type where the pulmonary conus is involved in developmental arrest and is narrowed In either type right ventricular hypertrophy is present and usually appears in precordial leads of the electrocardiogram Right bundle branch block is not rare in this condition (Fig 45A and B)

The electrocardiogram in tetralogy of Fallot In this common combined congenital lesion of the heart pulmonic stenosis is associated with dextroposition of the aorta ventricular septal defect and right ventricular hypertrophy The electrocardiogram shows marked atrial and right ventricular hypertrophy The P deflections are large and peaked especially in lead 2 Q3 is usually prominent and the T waves are often diphasic or inverted in the standard limb leads R waves are high in V_1 and VR and the S deflections are deep over V_5 and V_6 positions First-degree a v block may be seen frequently in the tetralogy while higher degrees of a v block and bundle branch block are less common (Fig 46A B and C)

The electrocardiogram in transposition of the great vessels This anomaly is probably due to failure of normal rotation in the early stages of heart development The pulmonary artery arises from the left ventricle and the aorta from the right ventricle Life depends on associated lesions The electrocardiogram shows no characteristic signs (Fig 47)

The electrocardiogram in tricuspid atresia There is an occlusion or hypoplasia of the tricuspid valve of infective or developmental origin A nonfunctioning right ventricle and hypoplastic or atresic pulmonary artery are concomitant findings in this malformation To be compatible with life this lesion inevitably presents an associated lesion or lesions of which the most common is an atrial septal defect

The electrocardiogram shows atrial and left ventricular hypertrophy Left axis deviation is usually but not always present depend

(*Text continued on p 75*)

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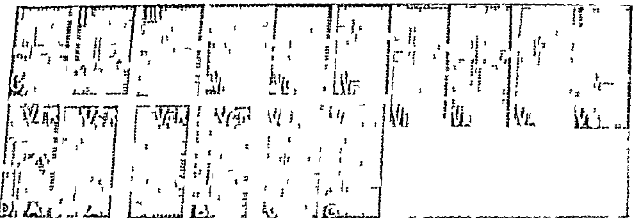
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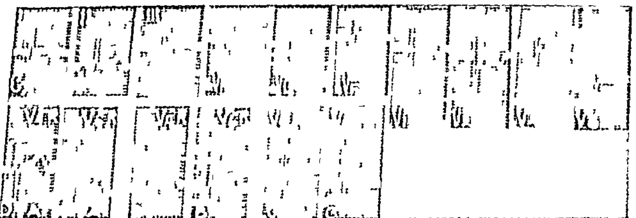
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C The same patient with arm electrodes reversed and the leg electrode attached to the right leg instead of the *left one In this instance also the tracing is similar to that of B*

D The true precordial leads V R and V R in this case seen in the three electrode po itions A B and C *noted above* The three types of tracings are alike



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The electrocardiogram in anomalous placement of tricuspid valves (Ebstein's disease) The posterior leaflet is displaced downward into the right ventricle Right atrial enlargement and tricuspid insufficiency are commonly present The electrocardiogram shows right atrial hypertrophy with large and wide P waves and frequent conduction disturbances Paroxysmal tachycardia and premature contractions may be of frequent occurrence (Fig 49)

The electrocardiogram in isolated ventricular septal defects (maladie de Roger) The lesion is commonly high in the septum and ventricular hypertrophy is uncommon The electrocardiogram is usually noncontributory to the diagnosis of this lesion Large diphasic QRS complexes with components of equal size (Katz Wachtel sign) may occasionally be present in two standard limb leads but this sign is not pathognomonic and may disappear in the older child

It is an interesting fact that conduction is so rarely affected in defects of the ventricular septum Even when the septum is absent as in *cor biatriatum triloculare* or *cor biloculare* and where the position of the bundle and its branches is most irregular conduction is rarely disturbed As the bundle develops before the development of the septum it is unlikely to be affected by later appearing malformations of the septum However complete or incomplete a v block does occur although rarely and bundle branch block also may be found in defects of the ventricular septum (Fig 50)

The electrocardiogram in single ventricle with rudimentary outlet chamber (cor biatriatum triloculare) There is a persistence of the common ventricle and bulbus cordis owing to an early arrest of development of the heart One or both vessels may arise

(Text continued on p 78)

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1 Tracing showing mirror image in lead 1 accompanied by upright P waves in this lead Ix On reversal of arm leads right becomes left axis deviation and on interchange of leads aV and aV the heart is seen to be in a semihorizontal electrocardiographic position

The patient was a 5 month-old girl (K.E.) referred by Dr Edward Hardy The infant showed no cyanosis and was well nourished and developed An isolated dextrocardia with persistent left aortic arch was present

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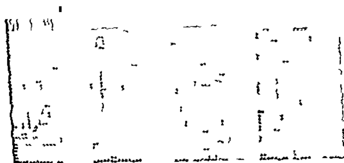


Fig 41 B

Fig 42. Tracing of 4-month-old cyanotic infant (I de C) with dextrocardia, situs inversus and signs suggesting *pulmonic* stenosis as the main lesion. The standard limb leads show marked deviation of the electrical axis to the left, which on reversal of the arm terminals (x) becomes marked right axis deviation. (Lead Ix should be read from right to left.)

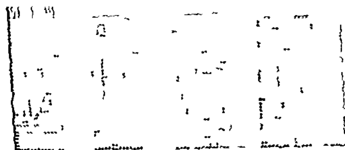


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atrial septal defect. The tracing shows evidence of right ventricular hypertrophy and large P deflections especially in lead 2 are present (Fig 52)

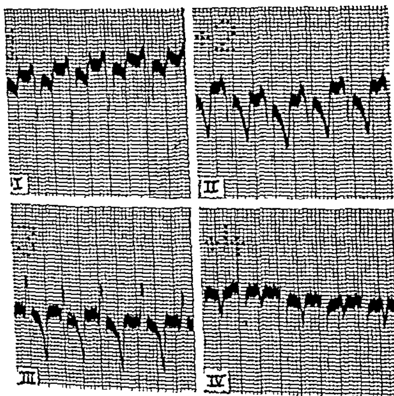


Fig 44 From an electrocardiographic tracing described by Dr Paul A di Sant Agnese et al as Case # 2 (W I) in their excellent paper Glycogen Storage Disease of the Heart. Pe[illegible]

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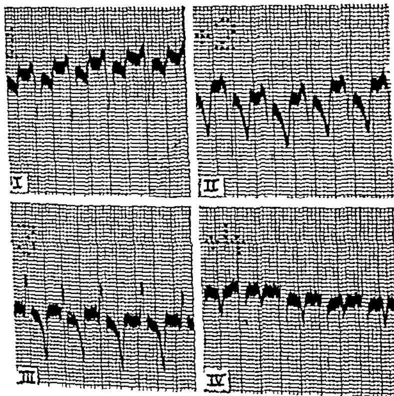
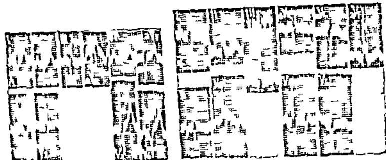


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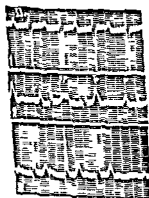


Fig 46 A Electrocardiogram of 16-month-old boy (E N) with clinical diagnosis of tetralogy of Fallot confirmed by autopsy Cyanosis and polycythemia were present A harsh systolic murmur was heard over the heart, loudest in the third left intercostal space The pulmonic second sound was diminished Under X ray examination the heart was seen to be boot shaped in the antero-posterior view with a concavity noted in the area of the pulmonary arc and the great vessels were of narrow width in this view The lung field u l n a

B Tracing of 7 year-old boy
Falot and right aortic arch wh , a ery was successfully anastomosed to the left subclavian artery

Marked right electrical axis deviation with vertical electrocardiographic po-

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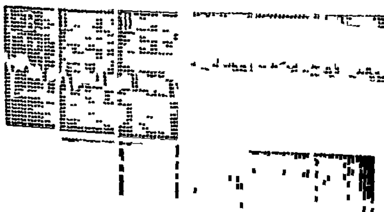


Fig 48 A Tracing taken on a 5 month-old girl (M H) who had shown moderate generalized cyanosis since birth A harsh systolic murmur was heard loudest over the third and fourth left intercostal spaces and was transmitted over the precordium and back A systolic thrill was palpable over the area of maximum intensity The X ray studies showed an absence of the pulmonary arc giving a bootlike cardiac shadow

The electrocardiogram is characteristic of right atrial and left ventricular hypertrophy Left axis deviation with horizontal electrocardiographic position of the heart is present. P deflections are large and peaked

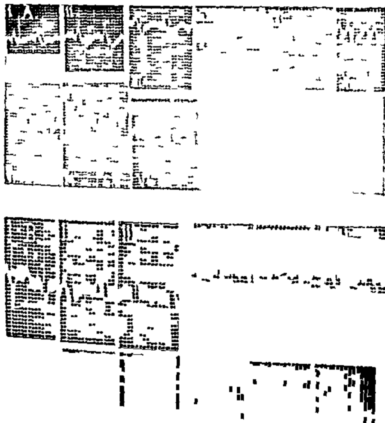


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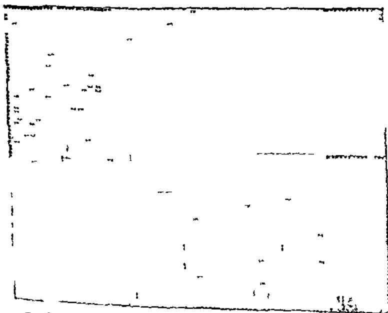


Fig. 50 Tracing from a symptom free 6 year-old boy (R O) with ventricular septal defect who showed a harsh high p tched systolic murmur at third left intercos al space which had been noticed since birth A systolic thrill was palpable in the same area X ray studies showed a normal heart outline The electrocardiog am shows sinus rhythm with no delay in conduction T waves are large

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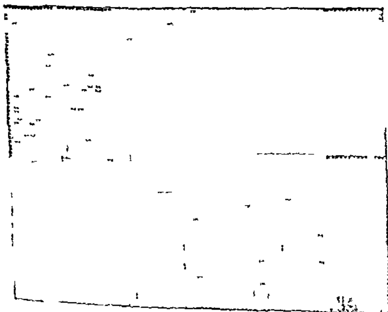


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B Tracing of 4-month-old Chinese girl (C Y) who entered the wards critically ill with pneumococcic meningitis No heart murmurs were noted but the child was cyanotic and died soon after admission

At autopsy a cor biatriatum triloculare was found The heart weighed 40 gm and was triangular in shape The aorta arose from the main chamber to the right of a small pulmonary artery which originated in a rudimentary chamber A single atrioventricular valve was present dividing the atria from the single ventricle A wide atrial-septal defect was present The standard limb lead tracing shows slight right axis deviation with elevation of the S-T segment in lead 2.

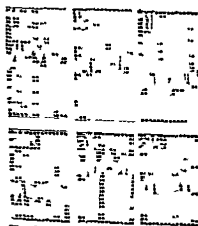


Fig 57 Tracing from 2 month old boy (I R) who was admitted to the wards in critical condition with marked cyanosis and dyspnea The heart was markedly enlarged A harsh systolic murmur was present (although at 4 weeks neither enlargement of the heart nor cyanosis had been present) Post mortem examination showed marked hypertrophy and dilatio of the right ventricle All pulmonary veins emptied into the coronary sinus which opened into the dilated right atrium The valve of the foramen ovale was open on the right. The tracing shows atrial and right ventricular hypertrophy Marked right axis deviation with vertical electrocardiographic heart position is present The P deflections are high and wide especially so in lead 2 R is of high amplitude in aV

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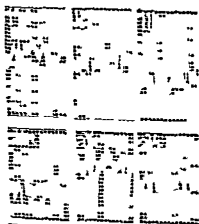


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brain lesions especially those affecting the medulla It may be noted in hypothyroidism Sinus bradycardia is rare in the cardiac child except as a digitalis effect Sinus arrhythmia and sinus arrest are usual accompaniments of a slow heart rate (Fig 53c)

Sinus Arrhythmia

Sinus arrhythmia is an irregularity of sinus rhythm in which the R R cycles vary more than 0 1 second The arrhythmia has no clinical significance and is common in the child especially so in those over 7 years of age (Fig 53d)

Sinus Arrest

Sinus arrest is an arrest of sinus rhythm in which a complete cardiac cycle is blocked or fails to appear The resultant pause almost equals two normal cycles The condition may be physiological and is not rare in the normal child (Fig 53e)

Premature Contraction

An abnormal heart contraction that arises from an ectopic focus and disturbs the regularity of the basic rhythm is a premature con traction Premature contractions may be of atrial atrioventricular nodal or ventricular origin They may be recognized in the electrocardiogram both by their abnormal position in the cycle and by their bizarre form A compensatory pause may be seen following the ectopic systole There is no compensatory pause when the ectopic beat is *interpolated* in a slow rhythm the prematurely contracted ventricle has then had time in which to recover from its refractory period and is receptive for the arrival of the normal excitation impulse (Fig 16) Premature contractions of each type may be found in the normal infant and child although those of atrial form are the most usual They are also found in acute rheumatic fever and other infectious diseases and in typhoid fever during the period of slow rate Premature contractions may also be present in con genital heart disease as in atrial and tricuspid valve anomalies although this finding is not as frequent as it is in the adult with an atrial septal defect

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Coupling or alternation of ectopic with regular contractions is not rare in children especially in those who have had recent pulmonary infections and during digitalis toxicity (Fig 54b and c)

Atrial premature contractions Ectopic P waves are usually inverted they appear prematurely and are followed by a P R interval that is not shortened Atrial premature contractions may be present in the normal child They may also appear in acute rheumatic fever and other infections They are occasionally seen in the child with congenital heart disease (Fig 54a and b)

A V nodal premature contractions arise in the atrioventricular node and cause the P deflection by retrograde action to appear just before during or after the QRS complex which is of supraventricular type Nodal systoles may be found in the normal child s tracing as well as in those with acute rheumatic fever and other infections (Fig 54c)

Ventricular premature contractions arise in ectopic foci of the ventricle The QRS complex so formed is bizarre in outline resembling somewhat the wide notched QRS curve of a blocked bundle branch The contraction may be of right or of left ventricular origin and may be recognized as such in the standard lead 1 If the main QRS deflection in lead 1 is upright the systole is of right ventricular origin if downward of left ventricular origin

Although less common in the normal child than *premature systoles* of supraventricular origin ventricular premature contractions do occur in the child without cardiac pathology They are more frequent in children with acute infections especially of *rheumatic* and pulmonary etiology and in nephritic and endocrine disorders

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a Sinus tachycardia with rate of 200 per minute in 8 month-old male with acute infection Atrial and ventricular complexes and intervals are of normal *outline*

b Same in 6 year-old girl with bro [illegible]

c. Sinus brad [illegible]

boy Heart rate [illegible]

complex Low U [illegible]

d. Sinus arr [illegible] with joint pains " The P P intervals vary in length

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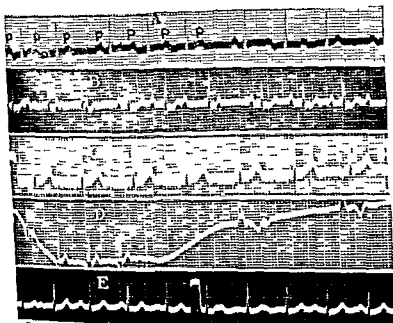


Fig 55 A, B Two cases showing Wenckebach s syndrome in 6- and 8 year old boys, respectively suffering with acute rheumatic carditis The P R intervals increase in duration progressively until the P wave falls during a refractory period of the ventricle and is blocked. The following P R interval is of normal duration and the cycle is repeated

C Atrioventricular or nodal rhythm in a 6-year-old normal boy with acute upper respiratory infection P waves are inverted, and the P R interval is shortened U waves are visible following the T deflections

D Paroxysmal a v rhythm in 8 year-old girl showing cardiac asystole and occasional ventricular escape beat during ocular pressure (Case of Dr Alfred Langmann)

E. A V interference dissociation appearing in an 11 year-old boy with rheumatic carditis (Case of Dr Herbert von Gal) The atria responding to the depressed S-A node beat at a slower rate than that of the ventricles which react to an ectopic focus in the a v node or ventricle

A V rhythm may be present as a congenital anomaly of conduction and is usually of little clinical significance The rhythm is often transitory and the position of the P wave may vary in respect to the QRS complex especially in those cases where a v rhythm is due to digitalis or other toxic effect (Fig 55C and D)

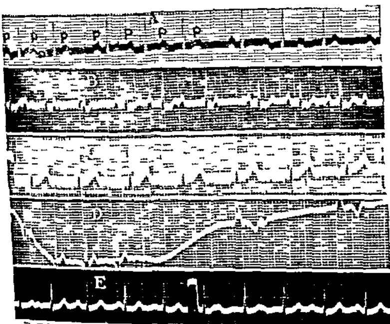


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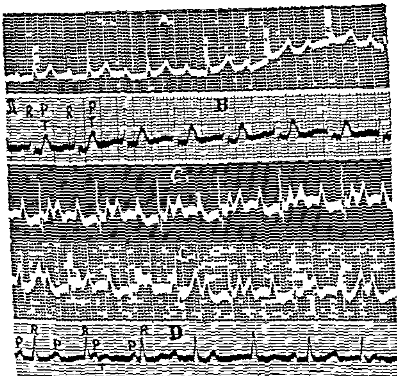


Fig 56 A First-degree a v block of transitory duration The P waves are notched and widened The P R interval is 0 3_ second The P R segment is lowered (Case of acute rheumatic fever)

B As in A P waves are superimposed on T deflections in 6 year-old child with a tive carditis

C i Second-degree a v block P and R waves fall regularly and P R intervals are equal The first atrial or P wave in each cycle is blocked by a refractive ventricle giving a ? 1 degree of block Note the Ta wave (inverted) following the second P deflections

C ii The same child as above during pha e of 1 1 1 a v block Three year-old boy with tetralogy of Fallot. The S-T segment is occasionally depressed by a Ta wave

D Complete a v block in an 11 year-old boy with ventricular septal defect P waves and R waves fall regularly but bear no relationship to on another The P R intervals are irregular

node during its refractile stage when the ventricular response being blocked no QRS complex will appear The succeeding P deflection is followed by a normal P R interval and the cycle of increasing a v conduction is repeated (Fig 55A and B)

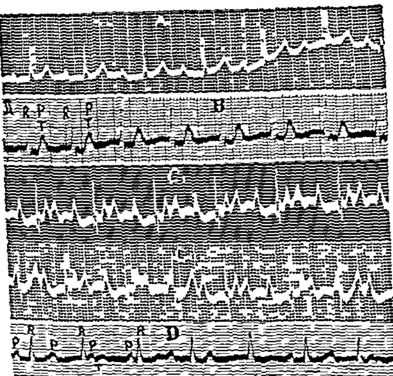


Fig 56 A First-degree a v block of transitory duration The P waves are notched and widened The P R interval is 0 3_ second The P R segment is lowered (Case of acute rheumatic fever)

B As in A P waves are superimposed on T deflections in 6 year-old child with a tive carditis

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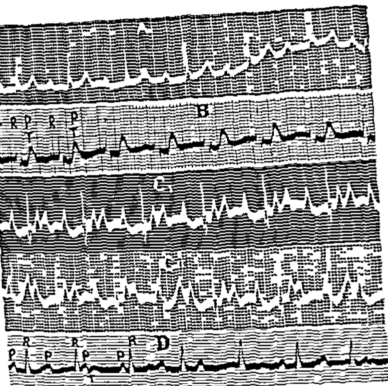


Fig. 56 A First-degree a v block of transitory duration The P waves are notched and widened The P R interval is 0 3. second The P'R segment is lowered (Case of acute rheumatic fever)

B As in A P waves are superimposed on T deflections in 6 year-old child with active carditis

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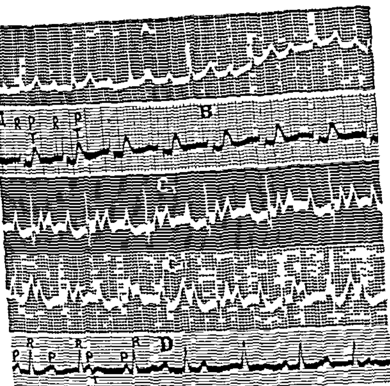


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or ventricle beat at a more rapid rate QRS complexes appear more frequently and usually without relation to P waves however, normal conduction may appear for one or more cycles in the course of the rhythm (Fig. 55E)

Atrial Paroxysmal Tachycardia

This is an abnormal transitory rhythm consisting of a phase of rapid atrial premature contractions which appear without pause regularly one after another The condition is occasionally seen in the newborn in whom no clinical evidence of cardiac disease can be found It may also be found in children with congenital heart disease especially in those with atrial and tricuspid leaflet anomalies in whom it may appear on effort or during acute infections It may occur in cases of short P R interval or Wolff Parkinson White syndrome It is not common in acute rheumatic fever although it may occur (Figs 26 49 [L2 and 3] and 57C)

Atrioventricular Nodal Paroxysmal Tachycardia

This is an ectopic regular rapid rhythm with its origin in the a v node P waves may precede or fall upon or follow the supraventricular type of QRS complexes which are dominant The tachycardia may appear in a normal child and no cause may be found It may be seen in children with congenital heart disease and in those with short P R conduction time (Figs 55D and 57D)

Ventricular Paroxysmal Tachycardia

This is an abnormal tachycardia which originates in the ventricle and consists of a succession of rapid and almost regular ectopic ventricular beats The rhythm is very rare in the child especially in those under 10 years of age It may appear in the rheumatic cardiac with widespread myocardial damage and rarely in congenital cardiacs (Fig 57E)

Atrial Flutter

Atrial flutter is a disorder of atrial conduction in which there are abnormal rapid and regular atrial contractions with a rate averaging

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common in atrial flutter seen in infancy Various degrees of block may be present in the same patient

The condition is rare in the child although many of the tachycardias found in the newborn are due to this condition and it may occasionally occur in the child with advanced mitral disease or in cases with hypertrophy and dilatation of the right atrium as in Ebstein s disease

The electrocardiogram shows toothlike regular atrial flutter waves which follow one another without pause and without respect to the ventricular responses which fall regularly usually with a 1 2 1 3 or 1 4 or mixed degree of block Flutter or fl waves are best seen in leads 2 and 3 and in V_1 and V (Fig 57B)

Atrial Fibrillation

Atrial fibrillation is a completely irregular heart action in which the atria are in a constant state of rapid irregular, and ineffectual motion and in which ventricular response is also irregular in force and rhythm Atrial activity is represented in the tracing by unequally sized and spaced small "f waves P waves are absent and the QRS complexes vary in voltage and appearance (Figs 21 25 and 57A)

Atrial fibrillation is rarely seen in the child It may be present in severe rheumatic carditis especially in those children who have greatly enlarged hearts and mitral lesions The rhythm may be paroxysmal or transitory in type and may appear as a sign of digitalis toxicity when it will disappear on the removal of the drug It may also occur as a transient finding in typhoid fever and diphtheria and has been found on embolization of a coronary artery from vegetative endocarditis

Ventricular Fibrillation

Fibrillation of the ventricles is a grave disorder of the heartbeat in which the ventricles contract with total irregularity of force and rate

The electrocardiogram shows large rapid irregular oscillations of

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Appendix

Boys

Age	Number of Cases	Average	±Standard Deviation	Range
3	9	0 13	0 04	0 12–0 15
4	18	0 13	0 03	0 10–0 16
5	24	0 14	0 02	0 12–0 17
6	29	0 13	0 02	0 11–0 17
7	33	0 14	0 02	0 11–0 19
8	31	0 14	0 02	0 10–0 18
9	33	0 13	0 01	0 10–0 16
10	27	0 14	0 01	0 10–0 18
11	19	0 14	0 01	0 12–0 16
12	15	0 14	0 04	0 12–0 18

Girls

Age	Number of Cases	Average	±Standard Deviation	Range
3				
4	22	0 13	0 01	0 10–0 16
5	33	0 12	0 02	0 10–0 16
6	29	0 13	0 01	0 12–0 16
7	35	0 14	0 02	0 11–0 16
8	30	0 14	0 01	0 12–0 16
9	6	0 14	0 02	0 12–0 16
10	18	0 14	0 02	0 12–0 16
11	21	0 14	0 02	0 12–0 16
12	9	0 14	0 02	0 12–0 16
				0 12–0 16

Table 8 Showing average P R intervals without reference to heart rate found in a study of [illegible] normal school children 3 to 13 years of age [illegible]

Appendix

Boys

Age	*Number of Cases*	*Average*	*±Standard Deviation*	*Range*
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				0 12–0 16

Table 8 Showing average P R intervals without reference to heart rate found in a study of [illegible] normal school children 3 to 13 years of age [illegible]

Cycle length	Square root
√0 44 sec	0 6635
0 46	0 678
0 48	0 692
0 50	0 707
0 52	0 722
0.53	0 727
0 54	0 735
0 56	0 749
0 58	0 760
0 60	0 775
0 62	0 787
0 64	0 800
0 66	0 812
0 68	0 825
0 70	0 835
0 72	0 855
0 74	0 866
0 76	0 870
0 78	0 882
0 80	0 895
0 82	0 905
0 84	0 915
0 86	0 927
0 88	0 935
0 90	0 950
1 12	1 06
1 16	1 08

Table 11 Approximate square roots of cycle lengths for use in determining QT_c values

Einthoven's Triangle

In an electrical sense the right shoulder the left shoulder and the left hip form an equilateral triangle in the frontal plane around the heart The heart thus lies approximately equidistant from each of the three points in the relatively homogeneous substance of the body The complicated pathway of electrical activity passing through the heart on atrial or ventricular activation may be reduced to a single vector which may be calculated from any two of the three standard leads by Einthoven's formula * or simply by using Einthoven's triangle which is a more crude but useful method (Fig 59)

* Tangent of alpha ? $\frac{e - e}{e \sqrt{3}}$ where alpha equals the angle between the axis and horizontal e the amplitude in millimeters of the *QRS* wave in lead 2 and e that of QRS in lead 3 The length of the axis or the manifest potential difference is calculated from $\frac{E = e_3}{\cos (a-60°)}$

Cycle length	Square root
$\sqrt{0.44}$ sec	0.6635
0.46	0.678
0.48	0.692
0.50	0.707
0.5	0.722
0.53	0.727
0.54	0.735
0.56	0.749
0.58	0.760
0.60	0.775
0.62	0.787
0.64	0.800
0.66	0.812
0.68	0.825
0.70	0.835
0.7?	0.855
0.74	0.866
0.76	0.870
0.78	0.882
0.80	0.895
0.8?	0.905
0.84	0.915
0.86	0.9_7
0.88	0.935
0.90	0.950
1.1_	1.06
1.16	1.08

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amplitudes in millimeters of R_3 and S_1 from the sum of R_1 and S_3 P D White suggests that if this index measures over 30 mm abnormal left axis deviation is present with normal border line of 20 to 30 if it measures under —15 mm abnormal right axis deviation is present with a normal border line of —10 to —15

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